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JAN 82 Y ALPEROVITCH, D MAY, P HO-SING-LOY N00014-78-C-0495
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**INFORMATION COLLECTION AND CORRELATION
SUPPORT SYSTEM FOR THE
MARINE CORPS TCO ENVIRONMENT**

Yoram Alperovitch
Don May
Paul Ho-Sing-Loy

Prepared for:
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes the implementation of an Information Collection and Correlation (ICC) decision support system to aid in the process of combat information evaluation in Marine amphibious operations. The system demonstrates the feasibility and effectiveness of the ICC concept by implementing several decision aid modules that were specified in last year's report. It aids the Intelligence Officer to organize numerous pieces of data received from different sensors into a cohesive and summarizing format. This is		

done by aiding the operator to generate and maintain different tracks, where each track must be supported by at least one sensor report.

The tracks reflect the analyst's knowledge about the reported entities while the supporting sensor reports reflect the facts that substantiate his process of deduction. The ICC system has been implemented on a portable computer and can be used as a nucleus for further development of the ICC concept.

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1. INTRODUCTION

This is a Final Report of the development and demonstration of an Information Collection and Correlation (ICC) decision support system for the Marine Corps TCO environment. This report completes a three-year research and development program that had the following objectives.

- (1) Analyze the MAB command and control environment in view of its tactical commander's decisions, information needs and operational objectives.
- (2) Develop a taxonomy of decision tasks encountered in the MAB decision-making environment, and identify classes of decision tasks requiring similar decision-making skills and cognitive behavior.
- (3) Develop a taxonomy of potential decision makers among MAB commanders at different levels and develop a taxonomy of available, as well as plausible, decision aids.
- (4) Identify the range of decision aids suitable for the MAB environment.
- (5) Recommend, using the taxonomy, high-payoff decision aids and select among them a decision aid well accepted by the users.
- (6) Design a software system for the simulation and demonstration of the selected decision aid.
- (7) Implement the decision aid in-house and demonstrate its operation.

- (8) Transfer the decision aid to the MTACCS Test Facility (MTF) and investigate the suitability of possible model generalizations.

During the first year of the program a methodology for decision aid selection for the Marine Amphibious Brigade environment was established. This methodology provides effective selection of decision aids by computing a figure of merit for each decision aid in any decision situation. The methodology also provides guidelines for implementation of the selected decision aid within the developmental effort.

During the second-year, the methodology was applied to selection of a decision aid for the MAB. This methodology was then tailored to the selection of a decision aid to be included in the Tactical Combat Operations (TCO) System. The application of this methodology yielded the Information correlation and Collection (ICC) decision support system developed for combat information correlation (See Appendix A.)

The third year of the program, that is documented in this report, included automation of selected decision aids and their integration into a stand-alone Information Collection and Correlation work station. It was developed and implemented on a portable Apple II computer. This system demonstration proved the feasibility and effectiveness of the ICC concept, while establishing a nucleus for further development and augmentation.

2. ENVIRONMENT OF IMPLEMENTATION

2.1 System Concept

During the second year of the program, a decision support system was designed that included two major elements: (1) an organizational structure and (2) a set of decision-aiding modules connected to each other within the organizational structure. The decision-aiding modules support the decision-making functions required for the performance of information correlation tasks. From an organizational viewpoint, correlation functions fall into two categories.

- (1) Local correlation, performed on sensor reports by Division, Wing, and MAF operators separately, and resulting in proposed track file modifications.
- (2) Global correlation, performed by a MAF operator on the proposed track file modifications, and resulting in a decision on proposed modifications with regard to their implementation.

This concept, depicted in Figure 2-1 shows the interaction of local and global correlations. Upon receipt of a sensor report, the local correlation operator (Div., Wing, or MAF) correlates this new sensor information with existing information contained in the track record file. When this local correlation process is completed, a proposed track file update is issued and sent to the track modifications file. The same decision-aiding modules support both local and global correlations that actually involve the same decision processes. The modules used by Intelligence Officers at both the local and global level fall into two categories: (1) information correlation, and (2) information collection. While information correlation is based on comparing pieces of information,

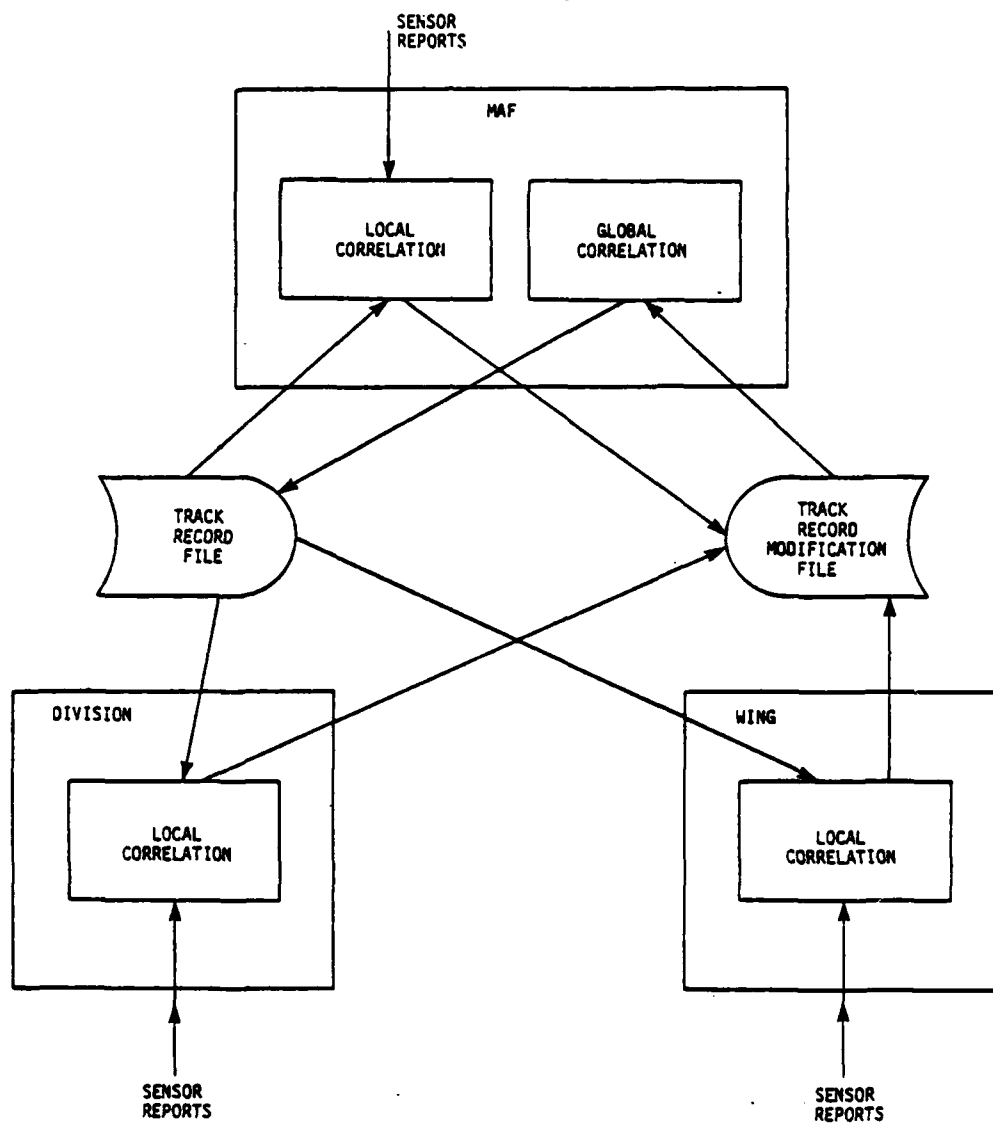


FIGURE 2-1.
DECISION SUPPORT SYSTEM CONCEPT OCERVIEW

information collection consists of selecting sources of information. The various techniques used to aid the processes involved in information correlation and collection were analyzed and concepts were defined.

2.1.1 Local Correlation Concept. As depicted in Figure 2-2, there are five decision-making functions involved in local correlation: (1) reliability assessment, (2) conflict identification, (3) conflict resolution, (4) information selection, and (5) track record file modification identification. These functions are sequenced as follows: upon receipt of a sensor report, its reliability score is computed; simultaneously, possible conflicts between the information contained in the sensor report and the track record file are identified. When a conflict is identified, the reliability scores are used to reject tracks with very low reliability, and possibly resolve the conflict. When it is not possible to resolve a conflict this way, more information is required. Thus, the most informative way to gather information is determined. The gathering of this information yields a sensor report that is again input into the system. When no conflict is identified or when the conflict is resolved, the proper track record file modification is determined and sent to the track record modification file.

2.1.2 Global Correlation Concept. Global correlation consists of comparing one element of the track record modification file to all others to determine whether to implement this proposed modification. The global correlation module should, therefore, enable comparison between any two proposed modifications to the track record file.

The functional similarity between global and local correlations is now apparent since they both involve the same functions except reliability assessment (see Figure 2-3). Since a modification to the track record file is proposed on the basis of a sensor report, the reliability score attached to this sensor report will be carried along with the proposed modification.

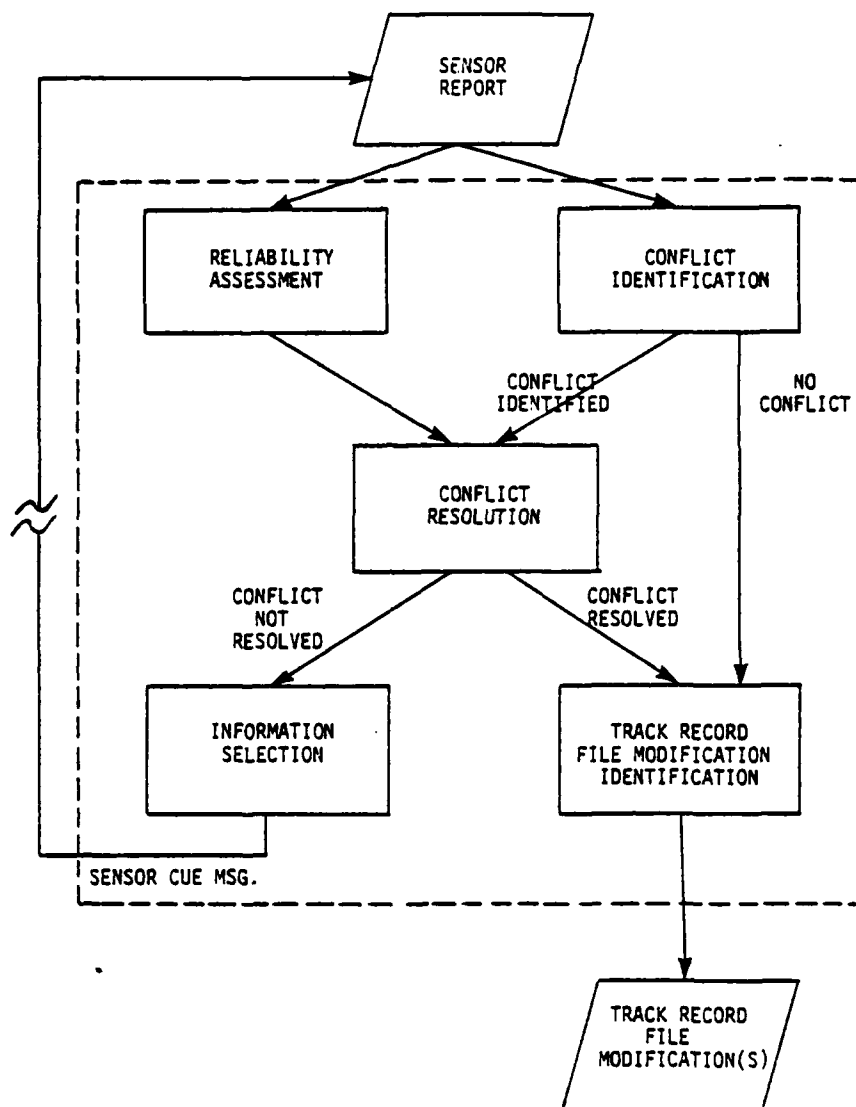


FIGURE 2-2.
LOCAL CORRELATION OVERVIEW

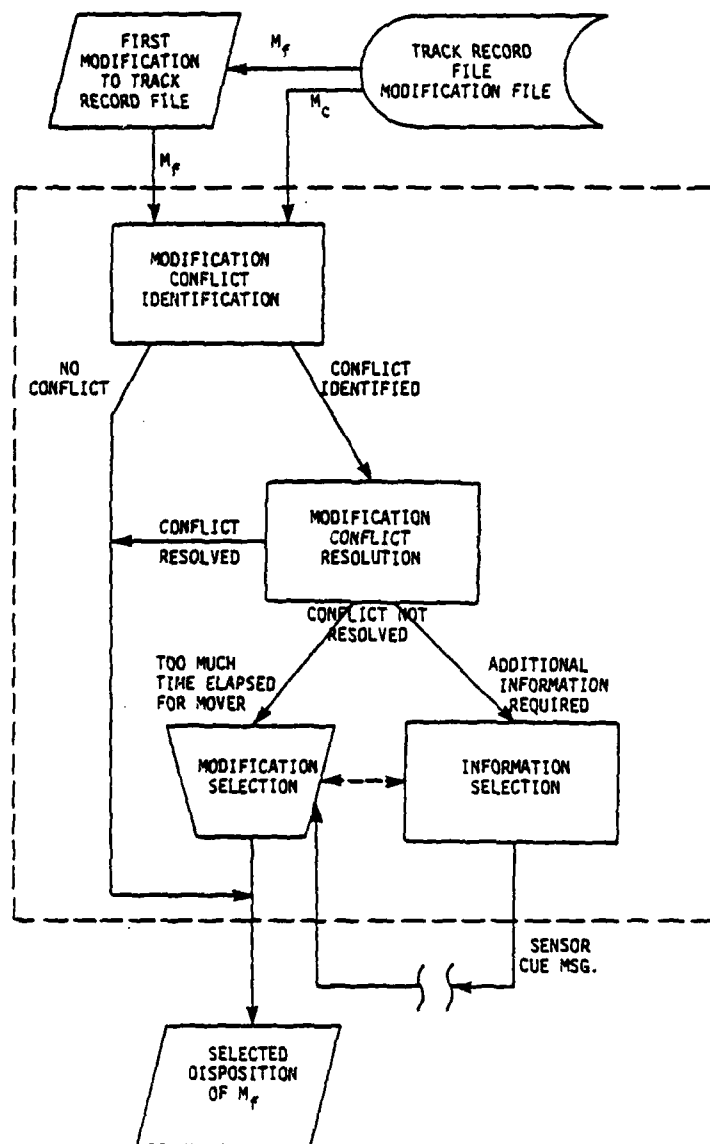


FIGURE 2-3.
GLOBAL CORRELATION OVERVIEW

Two proposed modifications to the track record file are compared for the purpose of identifying a possible conflict. When a conflict is indeed identified, the reliability scores are used to disqualify the sufficiently low-reliability modification, if such a case exists. In the case where the conflict cannot be resolved by the virtue of reliability scores, the most informative source of information for conflict resolution is identified and exploited.

2.2 Adapted Model

2.2.1 Automation Selection Criteria. Implementation of the complete Information Collection and Correlation System required resources beyond those afforded by the research program. To narrow down the scope of effort and because of high similarity among modules of the global and local correlation, only the local correlation process has been selected for automation. In order to specify a viable implementation within the Information Collection and Correlation (ICC) system as outlined in the system design document (Crolotte & Saleh, 1980), a number of tradeoff analyses between various implementation alternatives were performed. The main constraints considered were the following:

- (1) The implemented system should be effective.
- (2) The system should stand-alone, yet provide the nucleus for full-scale ICC implementation.
- (3) The functions automated first should be the ones normally selected based on human factor considerations.
- (4) The level of effort should be within the resources afforded by the contract.

2.2.2 Automation Option Selection. A number of options were considered consisting of individual functions or combinations of functions for auto-

I

mation. Based on the above constraints, the function, "reliability assessment," was selected for automation. Also retained for automation was the computation of the reliability index as an implied function. The automated functions are shown in Figure 2-4, which portrays the ICC functional overview. As can be seen, the reliability assessment function is totally automated. The conflict resolution, however, is partially automated since only the process of conflict resolution by means of disregarding low reliability pieces of information is addressed.

2.2.3 Proposed Outline. The system had to be specified in terms of: (1) automated functions (software implemented), (2) operator-performed functions, and (3) interfaces between automated and operator-performed functions (see Figure 2-5). The functional outline of the reduced system is depicted in Figure 2-6. This figure demonstrates that upon receipt of a sensor report, the reliability assessment module is activated and at the same time the operator is prompted to focus on the incoming information to identify those tracks in the active track file segment that contain information contradictory to the information just received. This results in a list (T-list) of tracks conflicting with the sensor report. An attempt is made to resolve the conflict on the basis of reliability. If this procedure fails, the operator is prompted to take over the conflict resolution function. If there was no conflict or if the conflict was resolved, the operator is called upon to correlate the information contained in the incoming sensor report with the current information in the track file. In this process, he uses, along with TCO-provided facilities, the reliability score attached by the system to every piece of information. The end result of the overall process is a proper modification of the track file.

2.2.4 Adapted Model. A detailed study of the available files in the TCO environment concluded that the external files cannot be easily accessed

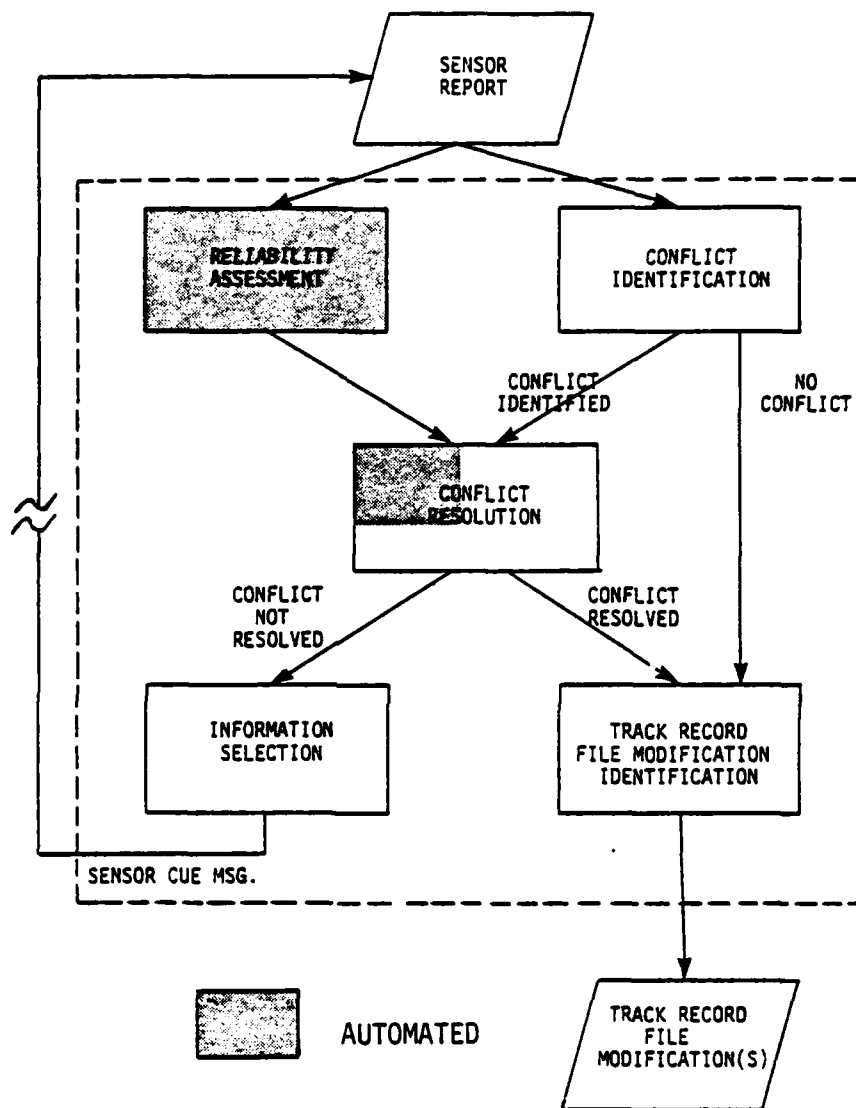


FIGURE 2-4.
AUTOMATED SYSTEM FUNCTIONS

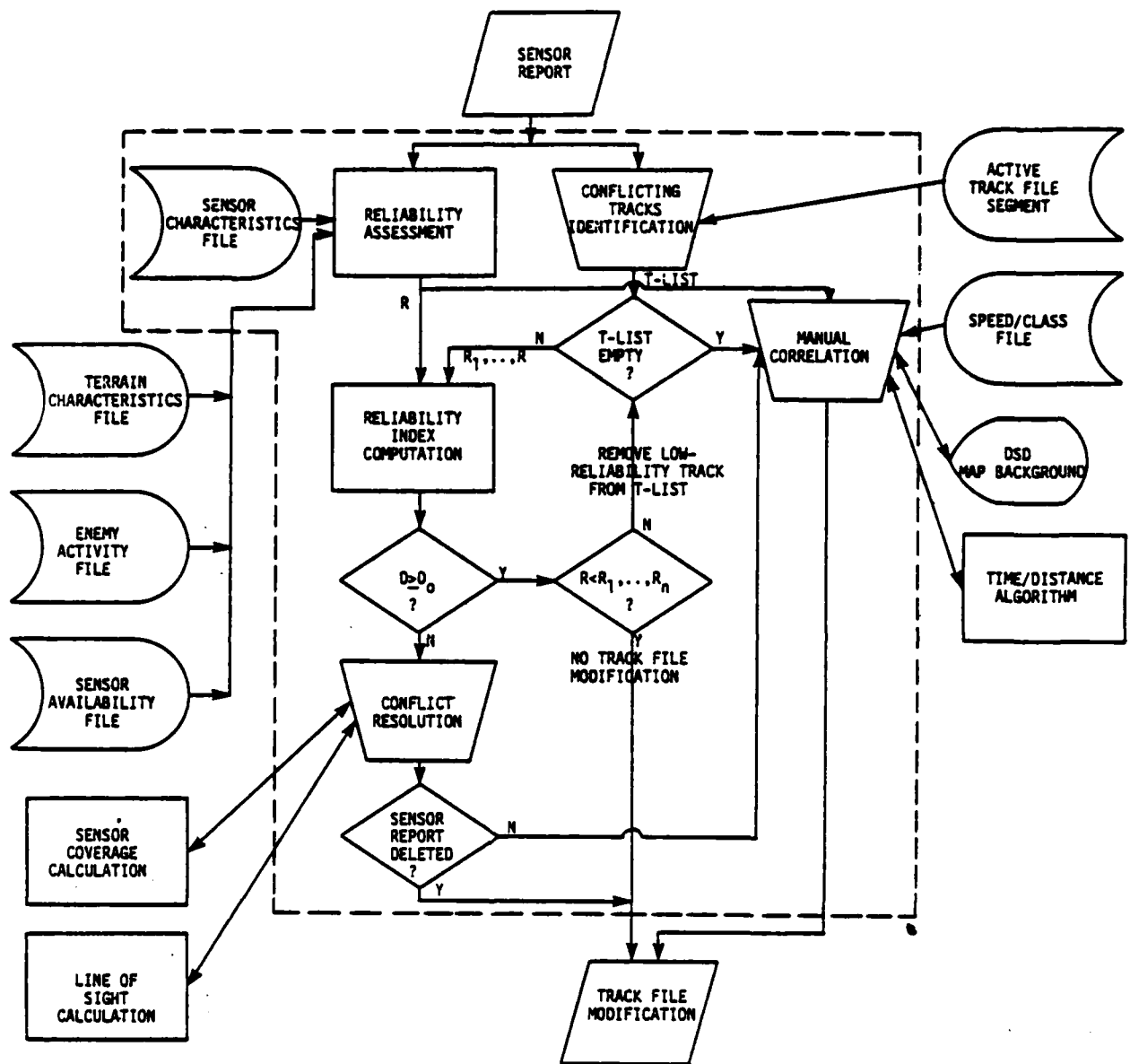


FIGURE 2-6.
PROPOSED SYSTEM FUNCTIONAL OUTLINE

by our application, and therefore every application of the ICC model also should contain the external files. The ICC model modifications were coordinated with and approved by the Marine Corps Tactical Systems Support Activity (MCTSSA), Marine Corps Base, Camp Pendleton.

The automation of the reliability assessment and conflict resolution modules also require a feedback element in order to demonstrate continuous operation of the system. The conceptual operation of the adapted model is as follows:

- (1) The model is a closed loop system so that early decisions have an effect on subsequent decisions.
- (2) The model aids the intelligence analyst in effectively organizing and structuring his knowledge by generating hypotheses that are inferred from the incoming stream of sensor reports.
- (3) Received Sensor Reports that are used to support one or more hypotheses are stored in the Active Track File Segment in conjunction with the hypothesis that they support.
- (4) Received Sensor Reports that are rejected are stored in the Rejected Sensor Reports File.
- (5) When receiving a new sensor report, the user can use it in support of an existing track or to generate a new track and support it by the new sensor report, or reject the new sensor report.
- (6) The same sensor report can support more than one track. Tracks can be conflicting or complementary.

These different functions of the adapted model are shown in Figure 2-7.

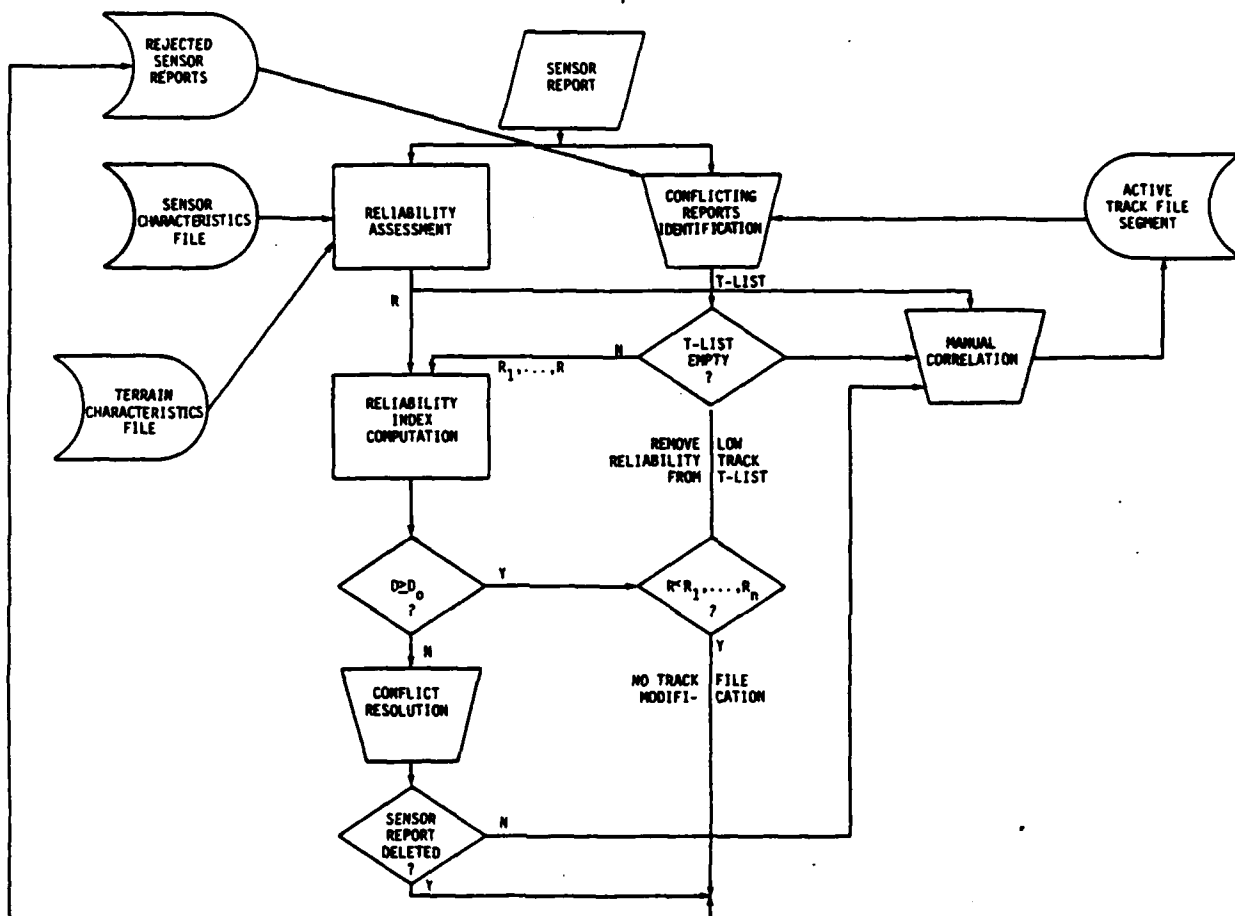


FIGURE 2-7.
ADAPTED ICC FUNCTIONAL MODEL

3. SYSTEM REQUIREMENTS AND DESIGN

3.1 System Requirements

The system must demonstrate continuous operation of the ICC adapted model by the following:

- (1) The user must be able to process an incoming Sensor Report (S.R.) at his own pace.
- (2) The user must be able to associate a new S.R. with old or new tracks (hypotheses).
- (3) The user must be able to reverse or modify his previous decisions concerning existing S.R.'s and tracks.
- (4) S.R.'s that are not used must be collected into a Reject File.
- (5) The system must aid the operator in automatic conflict resolution.
- (6) The system will be demonstrated on a preplanned scenario that generates S.R.'s that can be interpreted in more than one way.

3.2 System Design

3.2.1 Display Organization. Four fixed-size windows are displayed on the screen:

- (1) The top window contains a header line that relates to all the displayed records on the screen. Underneath the header is the Current Sensor Report line that displays a new S.R. whenever the user requests the next one.

- (2) This window displays the Active Track Records (ATR) with their supporting S.R.'s. The supporting S.R.'s are intended so the user can distinguish between ATR's and S.R.'s. An alternate context of this window is the Rejected S.R. File. It contains all the S.R.'s that are not supporting any ATR. The user is able to switch the context of the window and scroll every context forward or backward.
- (3) In the user's working area, the user can scroll S.R.'s, copy into or from it, and apply the automatic conflict resolution procedure on the records it contains.
- (4) The bottom window is the user-system communication area where the user types his commands and the system responds or prompts the user. It also displays a Help information.

3.2.2 Procedure of Operation. The adapted model, as shown earlier in Figure 2-7, contains three distinct phases that are steps in the processing of every new S.R. These phases are shown in Figure 3-2.

The Conflict Identification phase enables the user to associate a new S.R. with existing tracks, if any. All similar S.R.'s are copied into the working area. If a conflict exists between the new S.R. and other S.R.'s that were copied into the working area, the system applies its conflict resolution algorithm and recommends a candidate for deletion from the T-list.

Whether a conflict has been resolved or not, the user has to perform a manual correlation to accommodate the new S.R. (unless it was rejected by the conflict resolution procedure). The user can generate a new A.T.R. and support it by the current S.R. or use the S.R. to support an existing ATR. When the queue of S.R.'s is depleted, the session terminates.

	ENTITY DESCRIPTOR	ENTITY LOCATION	ENTITY ACTIVITY	SENSOR TYPE	TIME	RELIABILITY SCORE
(1)	CURRENT SENSOR REPORT					
(2)	ACTIVE TRACK RECORDS OR REJECTED SENSOR REPORTS					
(3)	T-LIST (USER'S WORKING AREA)					
(4)	USER-SYSTEM COMMUNICATION AREA					

FIGURE 3-1.
SYSTEM DISPLAY ORGANIZATION

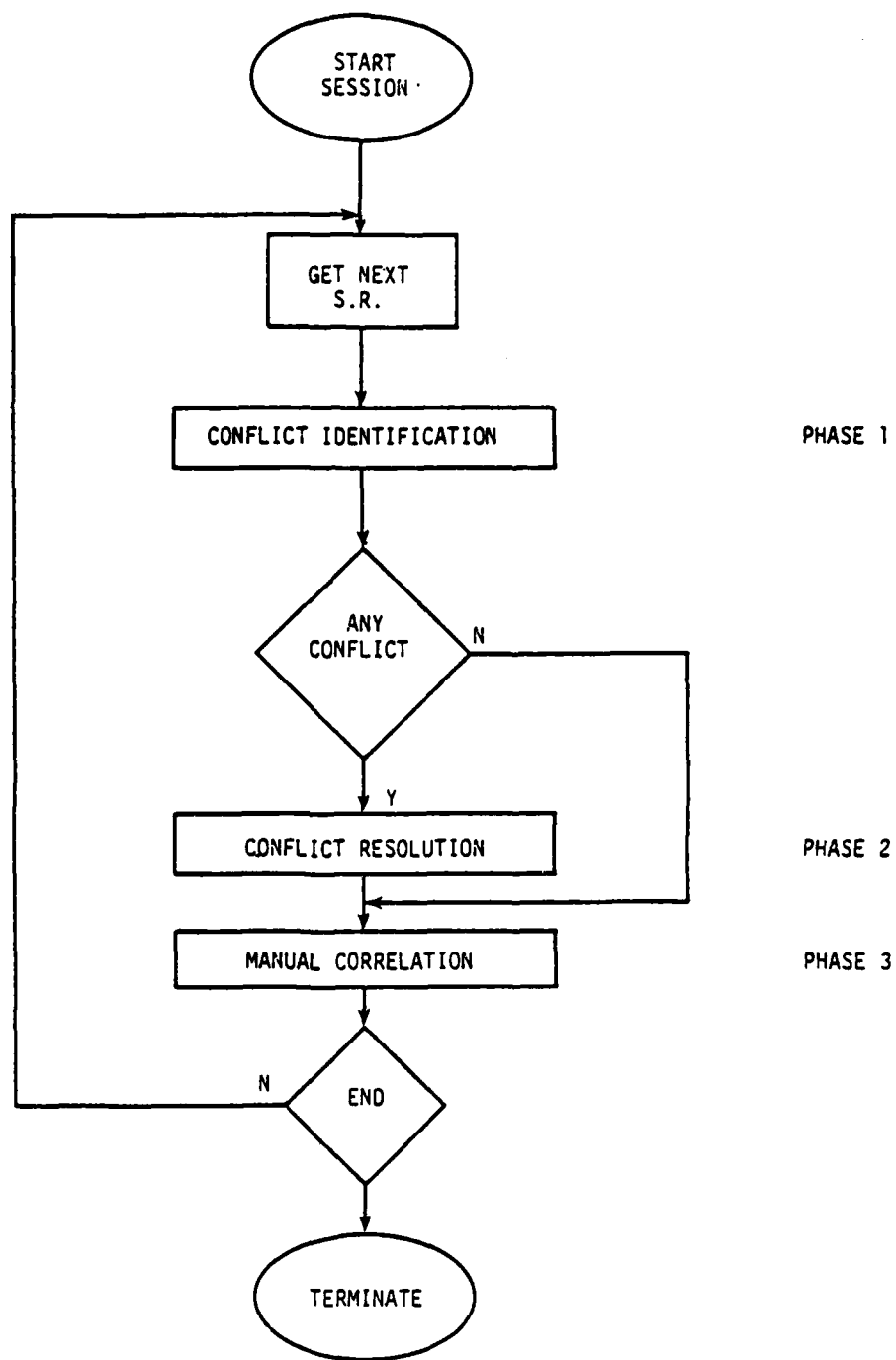


FIGURE 3-2.
PROCESSING STEPS OF EACH NEW SENSOR REPORT

3.2.3 System Commands. The following paragraphs define the commands and their functional operation from the operator's point of view.

- (1) WINDOW -- Each time the operator presses "WINDOW," the active window is changed (and the active record with it). The active record (and thus the active window) is indicated by a special cursor called "the active record cursor." The WINDOW, CONTEXT, and SCROLL commands apply to the active window; while ADD, COPY, CHANGE, and DELETE apply to the active record.
- (2) CONTEXT -- The CONTEXT command changes the context of window two between ATR and rejected SR's. The alternate context is saved for quick redisplay.
- (3) SCROLL (up and down) -- Each press of the button scrolls the active window and also changes the active record. SCROLL won't scroll down past the first record, nor up past the last record. The active record cursor remains in the middle of the record.
- (4) ADD -- ADD adds a record to the active track file only. Every ATR must have supporting SR's. This addition must be done with the COPY command. When the operator presses "ADD," the ADD command is acknowledged in the work area. The ATR is scrolled up leaving a blank line as the active record. Each field of the ATR is prompted in the work area. The operator inputs each field followed by return, and then that field is written in the active record line. Following the last field, the operator is reminded to use COPY to add supporting SR's to the ATR, then ADD exits.

- (5) COPY -- Four copy functions are allowed though all are not necessarily legal in each phase:

- (1) SR to ATR
- (2) SR to TLIST
- (3) SR (from AT window) to TLIST
- (4) TLIST to ATR

When COPY is invoked the following prompt occurs in the work area: "COMMAND COPY: FROM (active record) TO:". First, the user indicates the S.R. that he wants to copy, then he moves the cursor to the destination window and completes the operation.

- (6) CHANGE -- Only ATR's may be changed. To the user, CHANGE appears similar to ADD, except that the old field value is displayed in the prompt. The active record does not scroll up as with ADD but changes with each field input. The closing message is: "Remember to review the supporting SR's."
- (7) DELETE -- DELETE deletes the active record after first blinking it and eliciting the operator's confirmation (Y/N).
- (8) EXIT -- This command is used when the operator wants to exit from a phase. It must be legal to exit and a closing prompt must be answered. See Figures 4-1 through 4-4 for more detail.
- (9) HELP -- Gives a phase dependent help message.
- (10) NEXT -- Prompts the next S.R. in the top window.

3.2.4 System Demonstration. Figure 3-3 shows the complete configuration of the system that includes an Apple II with 24 by 80 columns board and a monitor. The software is developed in standard Pascal and can be trans-



FIGURE 3-3.
SYSTEM CONFIGURATION

ferred into any other machine with standardized Pascal compiler. One of the reasons for implementing the system on Apple II is its portability, which is a very important characteristic of any future ICC implementations. The system's size enables its easy transportation for demonstration purposes. Figure 3-4 shows the system display.

In the Figure, the top line is the screen header. Underneath the top line, the current sensor report is displayed. The second window shows the Active Track File that contains tracks and their supporting S.R.'s, which are indented. The first track is a Battalion Command Post, which is supported by three different S.R.'s. The second and third tracks are supported by one S.R. each. The current track is indicated by the star that appears in the rightmost column next to the Fortified Position track.

In this sample screen, two S.R.'s have been copied into the user's working area (the third window), indicating that the user regards them in conflict and probably intends to apply the automatic conflict resolution in order to decide if the lower probability S.R. can be deleted. The lower window is the user-system communication area. Automatic conflict resolution can be initiated by exiting from the conflict identification phase into the conflict resolution phase in which the system tries to resolve a conflict among the S.R.'s in the T-list. In the last phase, the user performs manual correlation by either (1) generating a new track that is supported by the new S.R. or (2) supporting an existing track by the new S.R. or (3) by executing both (1) and (2) when there is a possibility of two competing tracks, or finally, (4) deleting manually the S.R., whether automatic conflict resolution has been attempted or not.

4. SOFTWARE ORGANIZATION

4.1 Top Level Organization

The top level of the system is shown in Figure 4-1. The system is broken into 3 phases with pre and post session processing. The command functions are not explicitly shown at this level. An alternate design would have been to implement the 3 phases in a state machine. The present design has the advantage of making the session phases apparent from the code rather than from complicated state transition diagrams. Also the need for a message file is eliminated since messages can appear in the code when they are needed. This also makes the code more readable.

4.2 Second Level Modules

From the top level ICC System Figure (4-1), five secondary software modules are shown:

- (1) Initialization
- (2) Phase1
- (3) Phase2
- (4) Phase3
- (4) End of Session.

These modules create the session structure of the ICC system and can be described in terms of the operator's experience. They are described below.

4.2.1 Initialization (INIT) -- This previously displayed module initializes the display, sets window 2 context to display sensor reports, displays T-list if any, puts ATR if any in the alternate context display store, and sets the SR pointer to the next incoming SR.

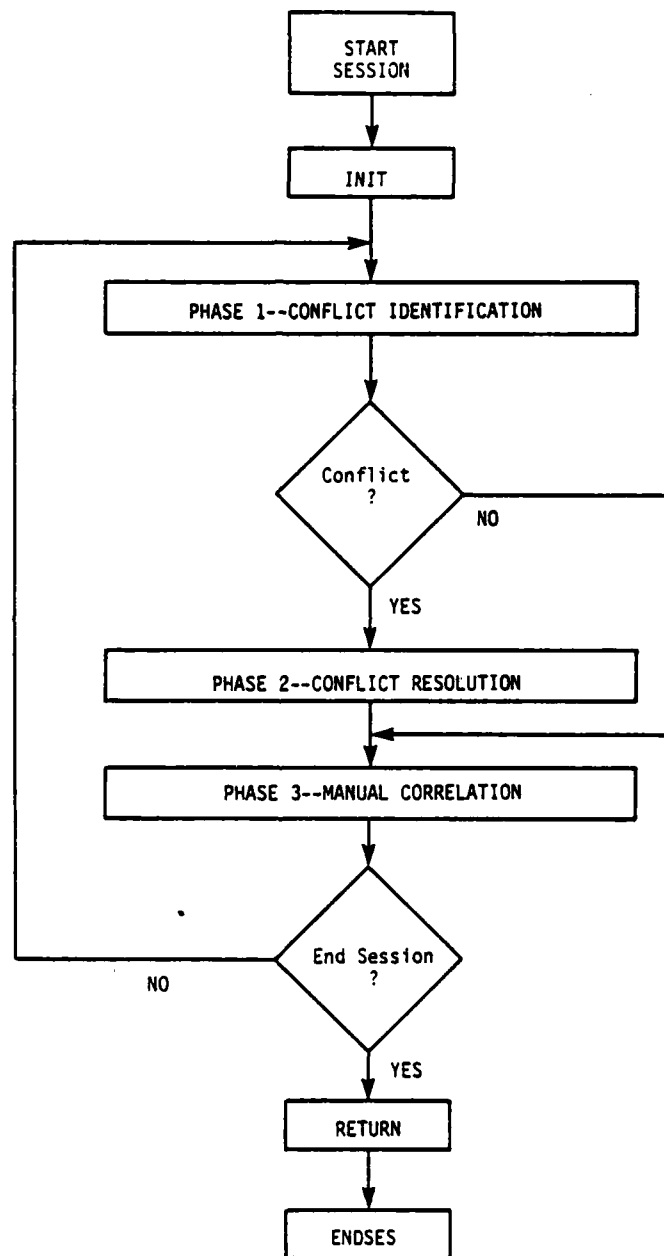


FIGURE 4-1.
TOP LEVEL OF ICC SYSTEM

4.2.2 Phase1 -- Conflict Identification. Figure 4-2 shows PHASE1.

In the first code segment, the incoming SR is displayed; the Conflict Identification phase is announced; and initial instructions are given. The command processor block is the same for all phases and is described in section 4-3. Functionally, it implements the commands described earlier. The last block identifies whether or not a conflict is elicited.

4.2.3 Phase2 -- Conflict Resolution. Figure 4-3 shows PHASE2. Automatic conflict resolution is attempted with the operator's approval. If automatic conflict resolution is not possible, the operator must resolve the conflict manually using the other commands. On exit, the operator is asked whether or not a conflict still exists.

4.2.4 Phase3 -- Manual Correlation. Figure 4-4 shows PHASE3. The task is to update the ATR. This includes adding, modifying, or deleting ATRs as well as supporting an existing ATR by new or old SR's. On entry, the phase is announced and commands are prompted until exit.

4.2.5 End Session -- ENDSSES. This routine does what little processing is required at the end of a session.

4.3 Command Processor

This third level module represents the bulk of the code in the system. It elicits input, recognition, and implements the command. The Command Processor contains procedures that correspond to each command described in section 3.2.

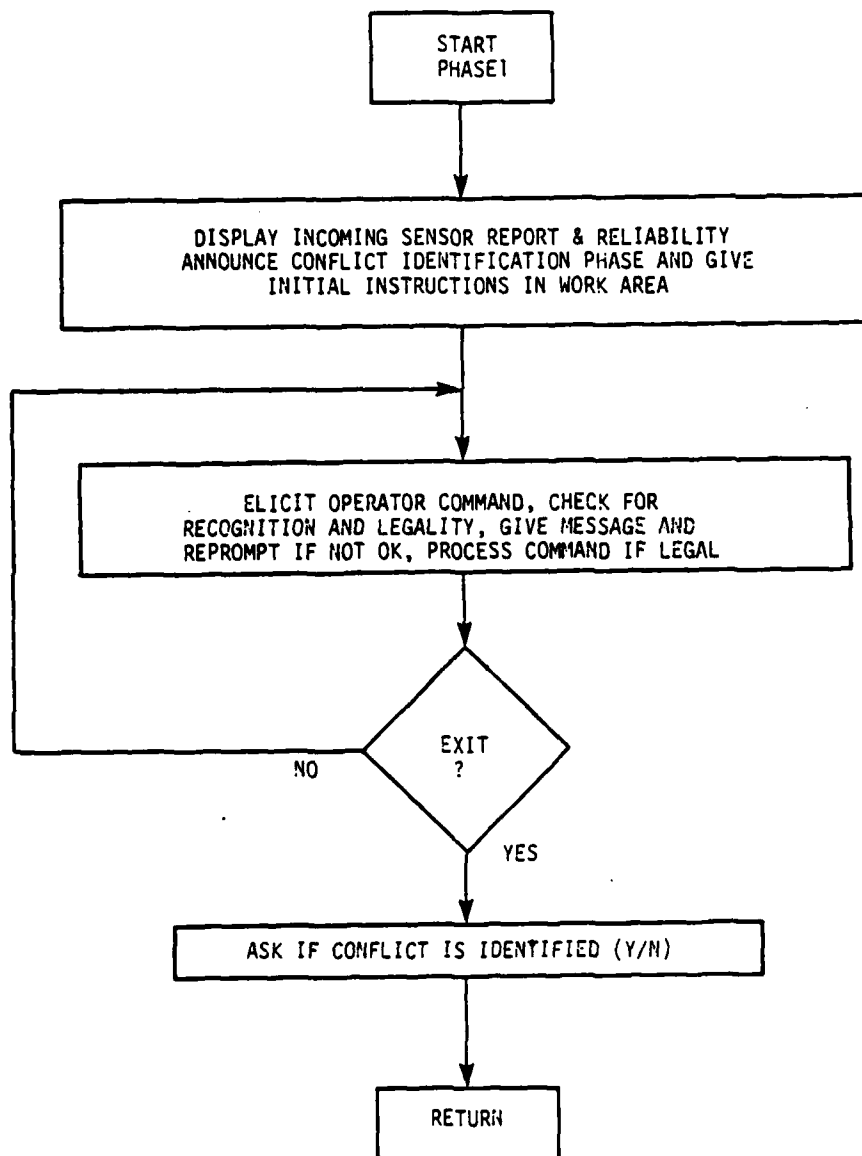


FIGURE 4-2.
PHASE 1-CONFLICT IDENTIFICATION

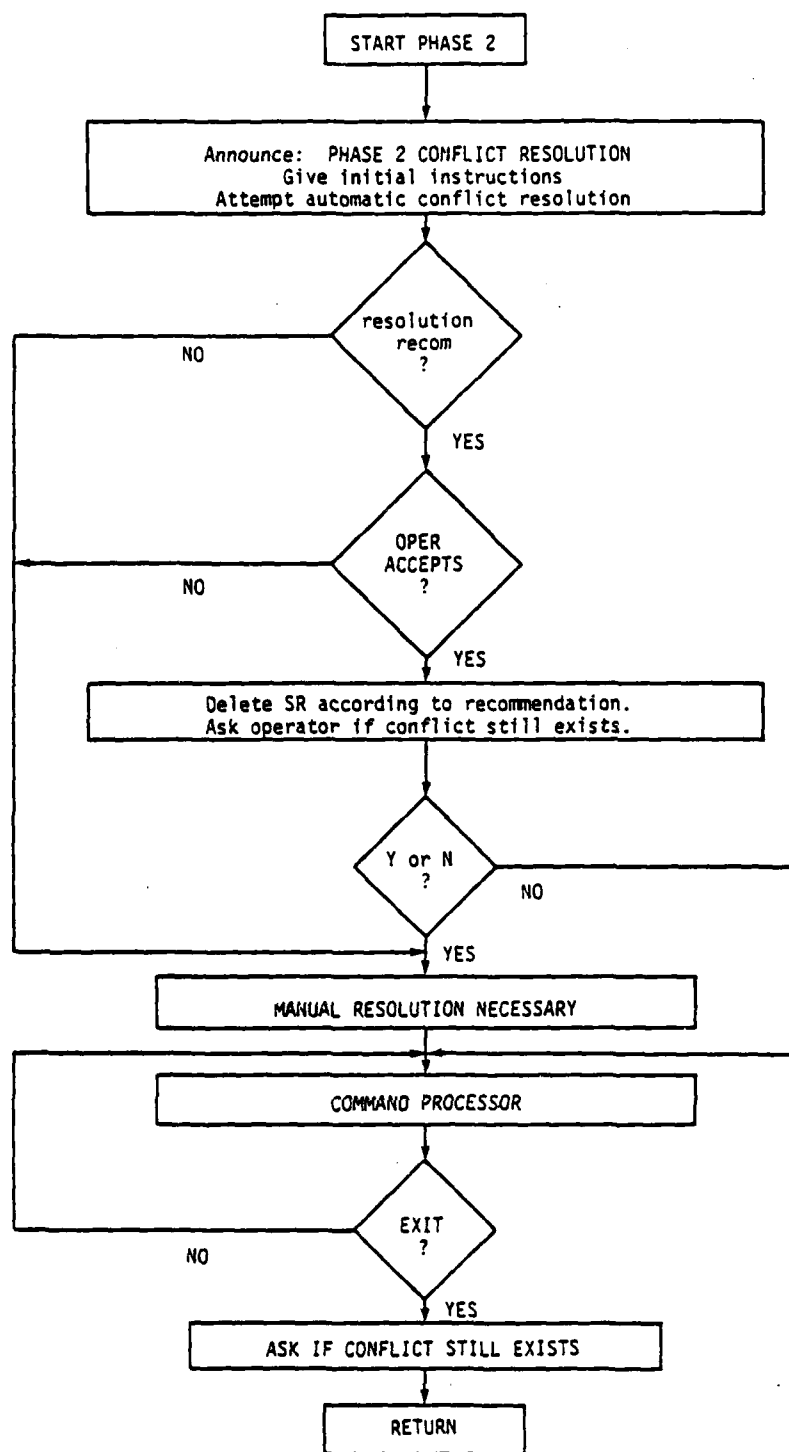


FIGURE 4-3.
PHASE 2-CONFLICT RESOLUTION

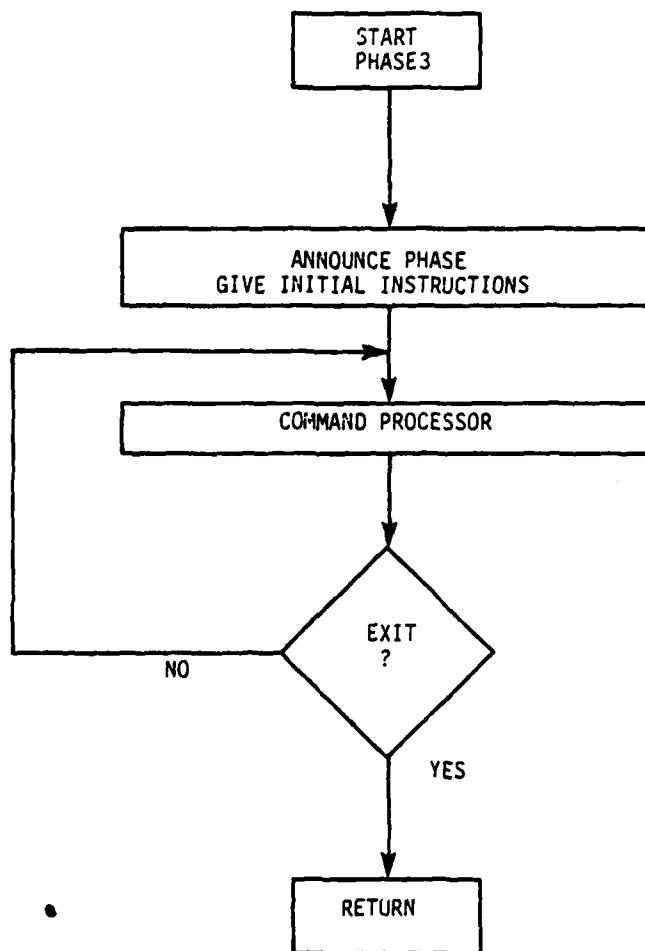


FIGURE 4-4.
PHASE 3-MANUAL CORRELATION

5. CONCLUSIONS

5.1 Scope and Limitations

Two major modifications were required in order to implement the proposed system: (1) adaptation of the model to handle in a closed loop process local information collection and correlation and (2) replacement of the TCO external files by the system's internal files. The demonstrated system does not have built-in facilities to handle real time sensor reports. Instead, it uses files that have been implemented from data of a specifically chosen scenario. Most of the utilities that were developed during the second year of the ICC project (see reference 1) were not implemented because of the limited scope of this effort. The automatic conflict resolution utility is therefore just a demonstration of the type of possible utilities that could be plugged into the system. However, though the software was implemented on an Apple II machine, the software can be easily transferred into a bigger machine with a compatible Pascal Compiler.

5.2 Contribution

This system demonstrated feasibility of the ICC concept. It serves as an aid for the intelligence analyst in the process of information collection and evaluation by helping the user to organize the incoming data into a semantically meaningful set of tracks. The required support of tracks by relevant sensor reports generates a collection of evidence and hypotheses. This aggregation of different evidence to support the same track can be viewed also as "aggregation by association" that makes the process of sensor report search, when performed by the user, relatively easy.

By supporting the intelligence officer in the task of data filing, retrieval, and data summary, this system can increase the total throughput of the analyst and speed up significantly the process of information assimilation and utilization. The function of the human information analyst cannot be performed by machines, but human efficiency and performance can be significantly augmented by utilizing adequate aids. The presented system is another step in that direction.

5.3 Further Research and Development

A few different directions should be evaluated before further development of the ICC concept is undertaken:

- (1) Implementation of the whole ICC model as it was documented in the Annual Report for last year, 1980.
- (2) Integration of an alphanumeric and a map display into one work station for increased efficiency and improved level of performance of the analyst who is using a manually arranged map display today.
- (3) Augmentation of the ICC model by incorporating smart agents; a package of AI procedures that performs the function of an "analyst apprentice." For example, for each new sensor report, the analyst apprentice will select previous sensor reports that have some association (like distance or time proximity) to the new sensor report.
- (4) A query language that enhances operator's performance by performing an intelligent search for a sensor report or a track that is specified in a non-procedural form.

Those research directions need not be exclusive and possible combinations should also be considered. Once an adequate ICC prototype system is developed, its integration with the Marine Air Ground Intelligence System (MAGIS) should be considered.

6. REFERENCES

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APPENDIX A

PROBLEM ANALYSIS

Introduction

Amphibious operations in the 1980's will be characterized by a combination of sophisticated weaponry, a high concentration of fire power, high speed of maneuver enhanced by the use of armored/motorized/mechanized forces, and enemy's capabilities to disrupt and deceive friendly forces.

"The term 'fog of battle' aptly describes the situation which will face the ground combat commander in this environment. Enemy electronic warfare and a rapidly changing situation will combine to give him scanty or erroneous information in some areas. In other areas the sophisticated communications and data collection capabilities available to him will tend to bury him in a flood of electronically generated raw data. If he is to prevail, he must be able to rapidly adjust his plans and execute changes to his scheme of maneuver to react to changes in the battlefield situation." (TCO Maneuver Control Paper.)

The combination of time pressure and information overload cannot be effectively coped with using the present tactical command and control system. This system works and has worked effectively for many years, but it is too slow to accommodate the requirements of the post 1980 battlefield. This operational deficiency was identified in the Required Operational Capability (ROC) document which states:

Technological progress has resulted in vastly improved sensor, communications, and automated processing capabilities. Automation is being introduced into virtually every functional area of command and control: fire support, air control, intelligence, logistics and manpower. After 1986, the unprecedented volume of information from these systems that is pertinent to tactical decisions cannot be received and processed at operation centers without the aid of automation. Current manual methods of message processing, data filing, retrieval, and posting to plotting boards are slow and

susceptible to inaccuracies and omission of relevant information and are, therefore, inadequate to support the timeliness and accuracy requirements of Marine Corps commanders in the post 1980's

As a result, the Marine Corps defined the requirement for a Tactical Combat Operations (TCO) System to overcome the identified operational deficiency of the present system. The ROC document briefly summarizes TCO as "An on-line, interactive, secure tactical command and control system designed to enhance the capability of the commander and his operational staff to conduct combat operations and planning."

A detailed description of TCO is included in the TCO Preliminary System Description Document (PSDD). Basically, the system consists of 92 capabilities which support a number of military functions. Again quoting the ROC: "As a minimum, TCO would provide additional support of the following functions:

- (a) Planning, coordinating and supervising the tactical employment of units.
- (b) Controlling the current ground combat situation.
- (c) Evaluating the tactical situation and preparing operations estimates.
- (d) Integrating fire with maneuver.
- (e) Receiving, transmitting, and displaying data/information.
- (f) Determining priorities for allocations of personnel, weapons, equipment and ammunition.
- (g) Preparing and distributing operations plans and orders.
- (h) Developing, preparing, and supervising the execution of training programs and field exercises.
- (i) Preparing and submitting reports."

TCO is envisioned as an information system in which microcomputers control interactive display devices, manage a distributed data base, perform computational tasks and generate hard copy records in order to provide automated assistance to the tactical commander and his staff in the areas of planning, intelligence and operations.

TCO is the focal point of the Marine Tactical Command and Control Systems (MTACCS) family, a conceptual association of eight command and control systems, interacting, functionally oriented and using the same design philosophy. The MTACCS Test Facility (MTF) at the Marine Corps Tactical Systems Support Activity (MCTSSA) (Camp Pendleton) provides a test bed for these systems by allowing simulation of real-life combat situations. System capabilities are simulated and their relative contribution to performance enhancement can be assessed (Kemple, Stephens and Crolotte, 1980).

Similarly, decision aids can be designed and implemented as system capabilities. The MTF offers an excellent opportunity for benchmark testing of decision aids. Once the effectiveness of the decision aids has been evaluated, a good basis exists for decision with regard to their actual inclusion into the system.

2.2 Aiding Requirement for TCO

In order to allow selection of a decision aid for inclusion in the TCO system, the decision aid selection methodology needed to be refined. As a preliminary step in defining this refined methodology, an assessment of the relative importance of TCO-supported decision task areas for mission effectiveness was carried out. This assessment was performed through a structured interview of Marine Corps personnel using a decomposition of TCO-supported Marine Corps functions. The most striking

result in this assessment is the overwhelming importance of operations (67%) and intelligence (25%) over planning (8% only). Rated very high in operations was ground maneuver control (23%).

The particular emphasis of ground maneuver control in Amphibious Operations is well-known and had been previously singled out by MCTSSA (TCO Maneuver Control Concept Paper). Ground maneuver takes its significance for units in contact with the enemy, i.e., at battalion level. *"The Marine infantry battalion is the basic tactical unit of the ground combat power in the Marine Corps. It provides the nucleus of the battalion landing team for amphibious and Marine amphibious unit air-ground task force operations."* (FMFM 6-3.) For these units mobility is the crucial issue and consequently any change in equipment apparatus, etc. should enhance their mobility--not hamper them.

As stated in the TCO Maneuver Control Concept Paper:

Commanders influence the conduct of maneuver by modifying the concept of operations, reallocating available assets or changing the missions of subordinate units. The decision to do one or a combination of these things is based on the information available to the commander; the quality of his decision will be directly related to the quality of the information available at the time it must be made.

Thus, timely and accurate information must be available to commanders in order to enhance decision making.

Decision making at battalion level is characterized by (1) time pressure and (2) information overload. To cope with these problems and be able to accommodate the needs of commanders out in the field for timely and accurate information, a number of TCO capabilities were designed. These capabilities are geared toward presentation of *near real-time graphic and*

textual display of tactical information on demand. It would provide the commander with the capability to develop, store, edit and disseminate, over standard communication links, information associated with the command, control, and coordination efforts. (Infantry Battalion Concept Paper for TCO.)

The actual production of real-time information gathered from various sources, in particular sophisticated sensors and automated data systems, poses the specific problem of information correlation. Information correlation was also identified as an important decision task area within intelligence.

At the present time, i.e., as described in the PSDD, information correlation is a TCO operator function. Consequently, aiding would be particularly suitable in this important area in order to speed-up the production of usable information and at the same time ensure accuracy.

Combat Information

As demonstrated earlier, commanders in the field require timely and accurate information. The type of information they require, however, must be clearly defined. From raw data to intelligence, information passes through various stages of processing. Raw data would certainly be timely, but it would be detrimental if non-accurate. In addition, raw data would probably be too voluminous to be meaningful. Buried in overwhelming amounts of raw data, the decision maker could easily overlook the important facts.

On the other hand, the intelligence process is often very long so that waiting for its completion to transmit information to commanders would not be acceptable. Consequently, somewhere between raw data and intelligence, an amount of data processing exists which realizes the best tradeoff between timeliness and meaningfulness.

Raw information is currently available to commanders through the use of the hot line. The drawback is that this information goes directly from the source (e.g., the BASS van) to the user and is not correlated with information coming from other sources.

Considerations of this sort led MCTSSA to define the notion of combat information (McDonough and Lawson, 1979) as: *that information about the location of enemy weapons, personnel and equipment on the ground which is made available immediately, after only technical processing. It differs from intelligence in that intelligence is the result of the analysis of many diverse elements of information and provides identification of enemy units as well as predictions and estimates of enemy intentions and capabilities. Combat information is the ground equivalent of the track information on enemy aircraft provided by the TAOC. It is utilized by intelligence analysts as one input in the production of intelligence. It is also used simultaneously by aviation and fire support agencies to select targets for immediate engagement and by maneuver control agencies to determine the objectives of maneuver and immediate threats to friendly forces.*

Although the term "combat information" is for many people a synonym of "unconfirmed intelligence," we have retained the definition of McDonough and Lawson (1979). This definition should, however, be refined since it is very hard to determine where correlation ends and analysis begins. A specific definition of what correlation consists of, i.e., the process it involves, therefore naturally yields a working definition of combat information. To illustrate the difference between combat information and intelligence, consider Figure 1 which depicts the interaction between G2 and commander during ground maneuver control. Under the scrutiny of a number of sensors, the environment provides information to the Reconnaissance and Surveillance station of the Intelligence Center. The sensors

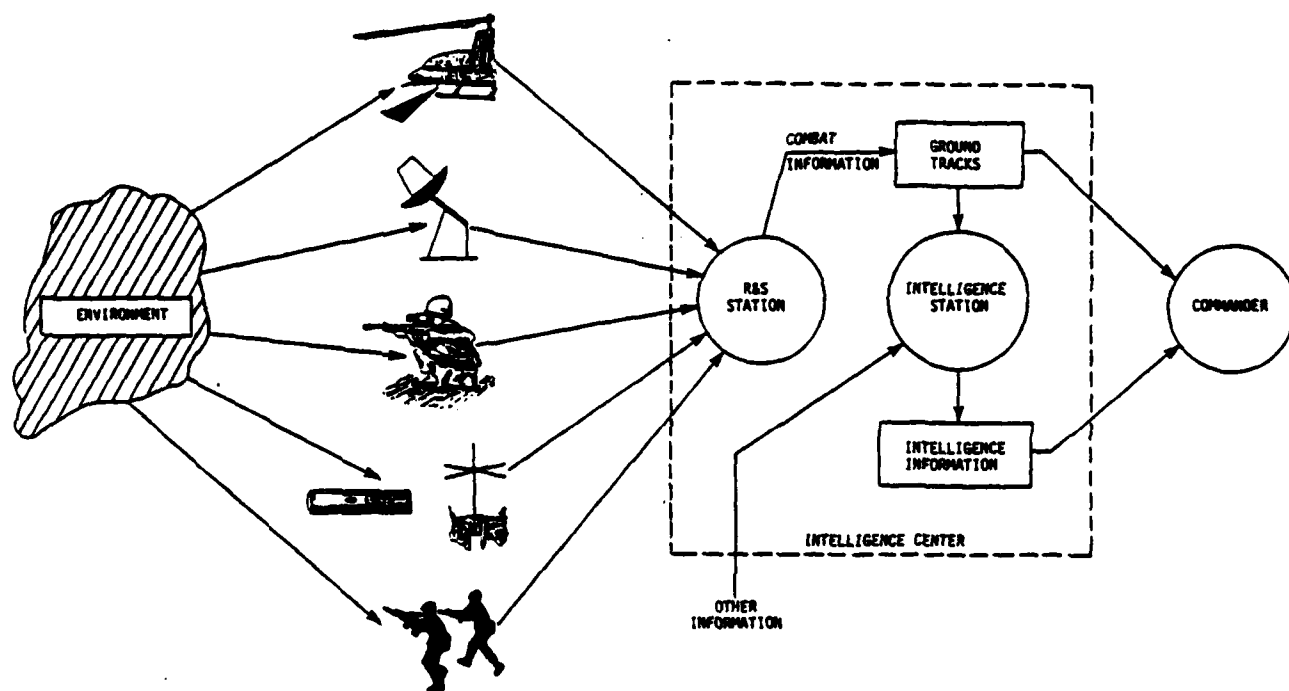


FIGURE 1
G2/COMMANDER INTERACTION DURING GROUND
MANEUVER CONTROL

portrayed in this figure are a helicopterborne infrared seeker, a ground surveillance radar, an individual served weapon sight, a hand-placed and an artillery delivered unattended ground sensor of the REMBASS generation and infantrymen in direct contact with the enemy. The Reconnaissance and Surveillance station creates ground tracks which represent the current picture of the battlefield together with its history. These tracks are available without delay to the commander and yet the information has been correlated.

The ground tracks are also available to the intelligence station within the Intelligence Center. Together with other information, these tracks allow the intelligence analyst to perform required analyses, estimates and inferences which are also very useful to the commander. The following example, extracted from the PSDD illustrates this point:

"The Battalion is operating at the Forward Edge of the Battle Area (FEBA). The Intelligence Officer receives a combat report from 'A' Company, who sighted an enemy tank forward of their position. The Intelligence Officer fills in an Enemy Sighting Report. Next, by a single action, he causes the report to be simultaneously automatically forwarded, to update his files, and to be graphically displayed on his enemy situation display. Reviewing the situation on his DSD, the Intelligence Officer notes an enemy track, received in response to a previous SRI, within 1000 meters of the sighting. He "hooks" the symbol and reviews the text display of the correlated combat information. The amplifying information indicates that five tanks suspected to belong to the 2d Bn 205th were sighted moving southwest two hours earlier. Noting the Unit ID, the Intelligence Officer recalls that recent intelligence summaries and responses to his previously submitted Ad Hoc queries had mentioned the 205th. Querying his intelligence files about the 2d Bn 205th the Intelligence Officer is provided known Unit Order of Battle information, which includes the enemy unit's strength and weapons. Equipped with all this information the Intelligence Officer makes his assessment. Contacting the Commander he warns that Company A's sighting is probably one of five tanks previously tracked and that four others are no doubt in the immediate vicinity. He Passes the same information to the CO of Company A, and he further alerts the Battalion and Company Commander to the combat power capabilities of the 2d Bn 205th."

Present Information Correlation Concept

This section summarizes the present concept of employment of TCO to support information correlation within the MAGTF as described at length by McDonough & Lawson (1979) and the PSDD. For additional details the reader should refer to these documents. For an amphibious operation of MAF size there are three intelligence centers each managing its collection assets as depicted in Figure 2 . For an operation of MAB size only one intelligence center exists managing all collection assets. Although defined at MAF level, the concept is immediately transferable to the MAB level. Raw data coming from a variety of sensors is received by division, wing, and MAF intelligence centers, correlated and included in the TCO data base. Combat information sources are portrayed and described in Tables 1 and 2 . A Combat Information Track record consists of the following data elements:

- (1) Track Identifier number.
- (2) Source(s) of the information.
- (3) Location (UTM coordinates):
- (4) Time of detection.
- (5) Classification.
 - (a) Troops.
 - (b) Vehicles.
 - 1 Tracked.
 - 2 Wheeled.
 - (c) Weapons (type).
 - (d) Emitters (Comm or Radar).
- (6) Number (of troops, vehicles and/or weapons).
- (7) Activity.

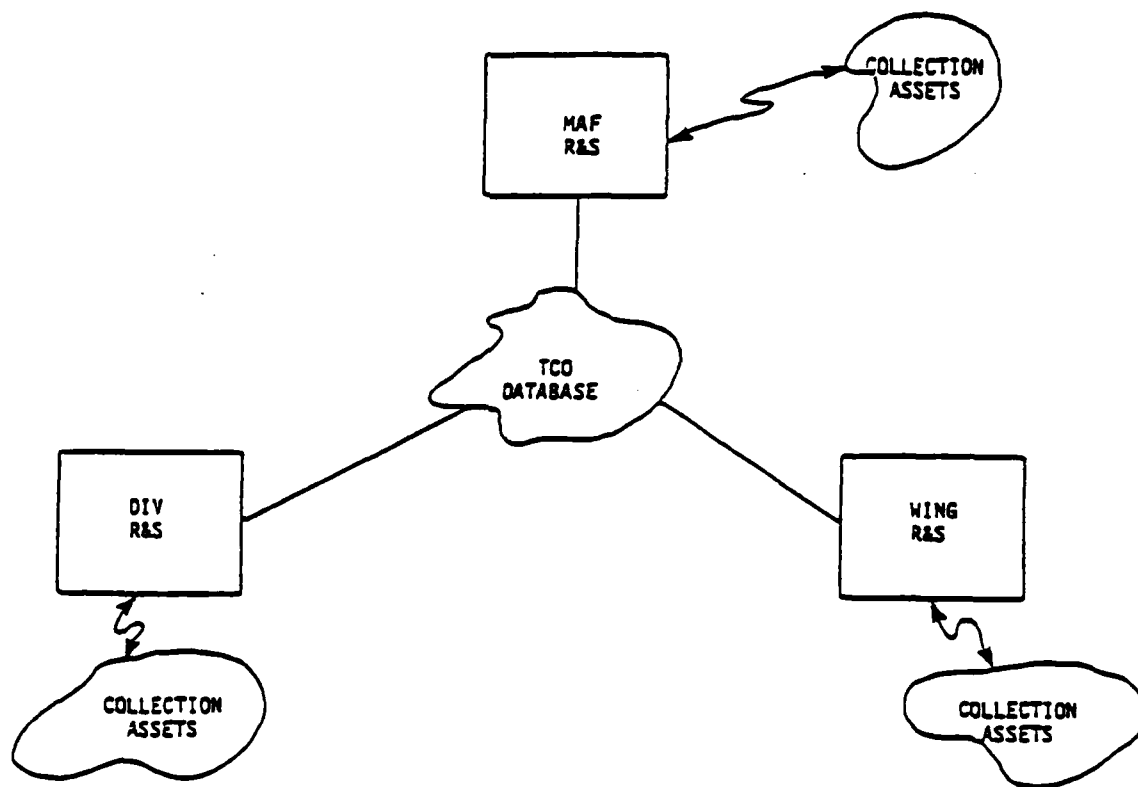


FIGURE 2
COMBAT INFORMATION FLOW

TABLE 1
COMBAT INFORMATION COLLECTION ASSETS

SENSOR TYPE \ UNIT	DIVISION					WING					MAF		
	INF. BAT.	RECON. BAT.	ART. REG.	SCAMP PLA.	ITT	WHO	VMA (AM)	VMFA F/18	VMFP	VMAQ	ELEMENTS RADIO BATTALION	TEAMS FORCE RECON	EXTERNAL SOURCES
UNATTENDED GROUND SENSORS	(1)			(7)									
GROUND SURVEILLANCE RADAR	(2)												
OPTICAL SIGHTS/SCOPES	(3)	(4)				(10)		(15)				(25)	
SIDE-LOOKING AIRBORNE RADAR									(18)				
INFRARED LINE SCANNER									(19)				
FORWARD LOOKING INFRARED						(11)	(13)	(16)					
MOVING TARGET INDICATOR							(14)						
PHOTOMETRIC		(5)			(8)	(12)		(17)	(20)			(26)	
DIRECTION FINDING											(22)		
COMMUNICATIONS COLLECTORS											(23)		
ELECTRONICS COLLECTORS										(21)	(24)		
COUNTER MORTAR RADAR			(6)										
TAPE RECORDER REPRODUCTION					(9)								
NATIONAL ASSETS													(27)
OTHER SERVICES SYSTEMS													(28)
ALLIED COLLECTORS													(29)

The numbers in circles refer to Table 2

TABLE 2
COLLECTORS OF COMBAT INFORMATION

AGENCY	NUMBER KEY	COMMON NAME	NOMENCLATURE	DESCRIPTION
INFANTRY BATTALION	①	MINI-PSID	Tactical Intrusion Detector (TID)	Miniature patrol seismic intrusion device lightweight, self powered, portable, seismic sensor.
	②		AM/PPS-15	Portable ground radar designed to acquire moving targets. Visual/audio signal. Personnel/vehicles.
		POLPEN-650		Foliage penetration, Battlefield Surveillance Device. All weather, all terrain, day/night observation, surveillance and target acquisition ground radar.
	③	Individual served weapon sight	AM/PVS-11	Small, lightweight all weather night observation telescope.
		Night Vision Goggles	AM/PVS-5	Infrared night observation head goggles used for close up work.
		Night Observation Device (NOD)	AM/TVS-4	Night observation device which utilizes starlight and moonlight for panoramic passive viewing.
		Starlight Scope	AM/PVS-2	Portable, battery powered, electro-optical instrument handheld or mounted on individual weapons.
DIVISION RECONNAISSANCE BATTALION	④	Starlight Scope	AM/PVS-2	Described in ③ above.
		Individual served weapon sight	AM/PVS-4	Described in ③ above.
		Night Vision Goggles	AM/PVS-5	Described in ③ above.
		NOD	AM/TVS-4	Described in ③ above.
		Crew served weapon sight	AM/TVS-5	Night vision sight utilizing starlight/moonlight and provides panoramic passive viewing.
	⑤	Camera	35mm HIROMOS II	Snapshot photographs.
ARTILLERY REGIMENT	⑥		AM/TPQ-36	Counter mortar radar.
SCAMP	⑦	REMBASS		Remote Battlefield Sensor System family of unattended ground sensors.
			DT 561	Magnetic
			DT 562	Seismic, acoustic
			DT 565	Infrared
			DT 567	Seismic, acoustic
			DT 570	Seismic, acoustic
INTERROGATION TRANSLATION TEAM	⑧	Camera	Polaroid	Snapshots of POW, captured documents, enemy equipment.
	⑨	Tape recorder reproduction set	AM/URF-3	Utility type portable tape recorder.
VMO	⑩	STEADY-EYE	SYD	Hand-held stabilized optical viewing device.
	⑪	NOS	Night Observation System	A forward looking infrared device used for night observation.
	⑫	Cameras	70mm panoramic Polaroid	Can be mounted to A/C hand-held snapshots.
VMA(AH)	⑬	FLIR	Forward Looking Infrared	Feature of the TRAN weapons system.
	⑭	MTI	Moving Target Indicator	Locates and tracks moving enemy ground targets in the target area.
VHFA (F-18)	⑮	Optics		Optical/electro-optical sights support the A/F-18 pilot.
	⑯	FLIR	Forward Looking Infrared	
	⑰	Cameras		The aircraft is capable of being equipped with photographic equipment.
VPM	⑱	SLAR	AM/APD-10	Produces radar imagery on film (can be down linked).
	⑲	IR	AM/AAD-5	Produces infra red photography.
	⑳	Cameras	Photo	Panoramic and vertical imagery, B&W, color, camouflage.

TABLE 2 (CONT'D)

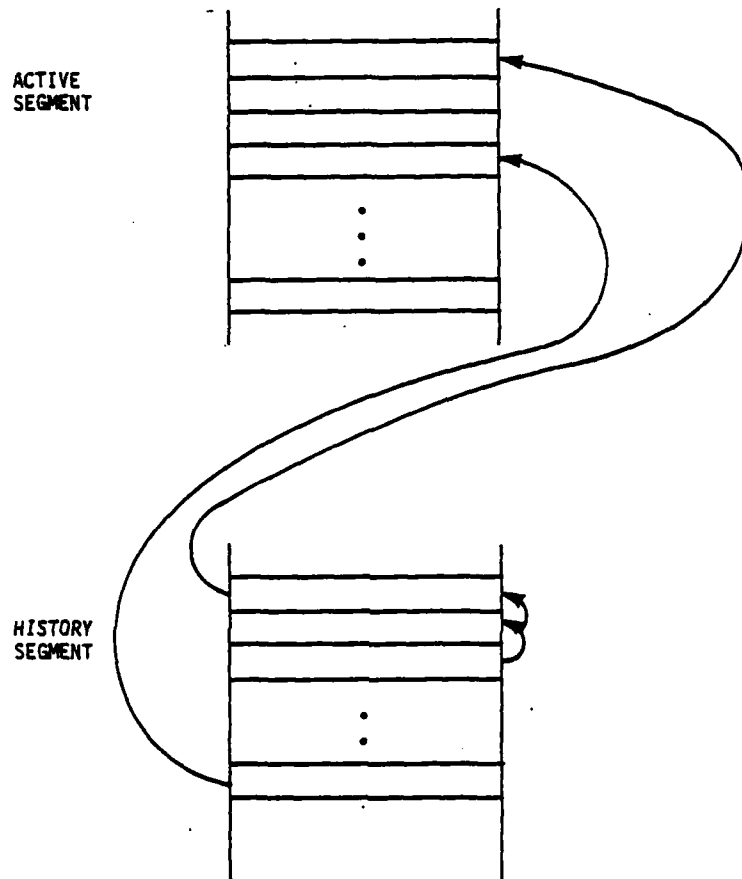
AGENCY	NUMBER KEY	COMMON NAME	NOMENCLATURE	DESCRIPTION
VMAQ	(21)	ELINT		Electronics intelligence collectors.
RADIO BAT.	(22)	D.F.	AN/MRD-16 AN/GRA-94 ARDP	Mobile radio direction finding (D.F.) set. D.F. radio. Team portable, omni directional airborne radio direction finding system. Mounted to UH-1H helicopter type.
	(23)	COMINT	AN/TSQ-54 AN/TSQ-88 AN/TSQ-103 AN/PRA-640 AN/TRQ-30	Communications intelligence collectors. Heavy mobile intercept facility, voice, Morse and teletype. Multichannel communications collection van. Mobile, light intercept facility. Man-packed radio receiver set. Single channel man-packed intercept receiver set.
	(24)	ELINT		Electronics intelligence collectors.
FORCE RECONNAISSANCE TEAMS	(25)	Starlight Scope	AN/PVS-2	Force Reconnaissance is equipped with devices identical with those identified for Recon B 4 above.
		Individual served weapon sight	AN/PVS-4	Described in (4) above.
	(26)	Camera	35mm NIKONOS	Snapshot photographs.
EXTERNAL SOURCES	(27)	National Assets		CLASSIFIED
	(28)	The following systems operating adjacent to	Identify sources providing combat information from other artillery services or in conjunction with the MAGTF.	
		ASAS		All Source Analysis System (U.S. Army).
		AETELIS		Automated Ground Transportable Emitter Location-Identification System (U.S. Army).
		SOTAS		Staff Off Target Acquisition System (U.S. Army).
		TACELIS		Tactical Emitter Location and Identification System (U.S. Army).
		QUICKLOOK 11	AN/ALQ-133	CLASSIFIED (U.S. Army).
		TRAILBLAZER	AN/TSQ-144	CLASSIFIED (U.S. Army).
		GUARDRAIL V		CLASSIFIED (U.S. Army).
		MULTENS		Multiple Target Electronic Warfare System (U.S. Army).
		QUICK FIX	AN/ALQ-151	(U.S. Army).
		BSTAR		Battlefield Surveillance and Target Acquisition Radar (U.S. Army).
		ALA	AN/TPQ-37	Artillery Locating Radar (U.S. Army).
		RPV		Remotely Piloted Vehicle System (U.S. Army).
		NEDS		Nuclear Burst Detection System (U.S. Army).
		TSSLs	ROLM 1602	Tactical Single Station Locator System (U.S. Army).
		RTASS		Remote Tactical Airborne SIGINT System (USAF).
		COMPASS EARS	AN/ASQ-114(V)	(USAF)
		RIVET JOINT		CLASSIFIED (USAF)
	(29)	The following allied systems typify automated systems which might provide combat information to the MAGTF.		
		BATES		United Kingdom. Battlefield Artillery Target Engagement System.
		MAVELL		United Kingdom. Provides G-2/G-3 support similar to TCO.
		BEROS		German.
		GEADGE		German Air Defense Ground Environment
		ATILA		French.
		ODIN		Norwegian.
		SAGAT		Italian.
		CCOS		Canadian.

- (a) Moving (direction/speed).
- (b) Deployed.
- (c) Assembling.
- (d) Emitting.
- (e) Firing.

(8) Unit I.D.

The Combat Information available is summarized in the track record file which is divided into two segments as depicted in Figure 3: (1) the active segment which contains the most current track data and (2) the history segment which summarizes past track behavior.

When a sensor report is received at the center, the corresponding information is correlated with existing tracks to determine if it corresponds to (1) a new track, (2) an update of an existing track, or (3) redundant or less reliable data about an existing track. This correlation is performed by an operator aided by displays on the Dynamic Situation Display (DSD). If a new track is created the operator assigns to it an identifier from an authorized set of numbers and the track is entered in the track record file with a prefix referring to the track manager (e.g., D for division). A center which creates a track automatically becomes the manager of this track. Upon updating by an R & S station of a track which is under management of another R & S station, both stations must agree on the proposed update. Conflicts are referred to the track coordinator located in the MAF intelligence center. In the present concept MAF track correlator and track coordinator are the same person. In addition to resolving conflicts the track coordinator may reassign track management responsibility from one center to another.



The arrows are pointers identifying all the data elements which constitute a track.

FIGURE 3
COMBAT INFORMATION TRACK RECORD FILE

Areas of Improvement

In the present concept of employment of TCO support of combat information production and management, the operator correlates information manually with the aid of certain TCO capabilities of a general supportive nature only, such as time computations, displays of ranges and line-of-sight calculations. These capabilities probably make the operator's job easier and enhance accuracy and timeliness. They do not, however, provide any direct aid to the decision processes which are involved in information correlation, thus do not significantly reduce processing time. At the estimated rate of 600 sightings per hour shared between division, wing, and MAF operators, i.e., on the average one sighting every 20 seconds, it is very likely that a task overload would occur. In the decision support system concept presented in Chapter 3, the information correlation decision process is decomposed into elementary decision sub-processes which are automated or aided. It is expected that, by employment of the support system, the average processing time per sighting will be much shorter so that those sightings which require operator intervention can be allocated more time.

The process of information correlation involves comparing pieces of information to decide if they refer to (1) the same entity or (2) two distinct entities. When referring to the same entity the pieces of information can either be in accord or create a conflict. If a conflict between two pieces of information occurs, one must be able to compare these information in terms of the credibility or reliability which can be attached to them. Even if there is no conflict, it is essential to be able to decide if a piece of information is unreliable in order to disregard it. If a conflict cannot be resolved by discarding the less reliable information, more information needs to be collected. A decomposition of the decision functions involved in the process of information correlation is presented in Figure 4. In the following chapter the proper aiding techniques to support these functions are described.

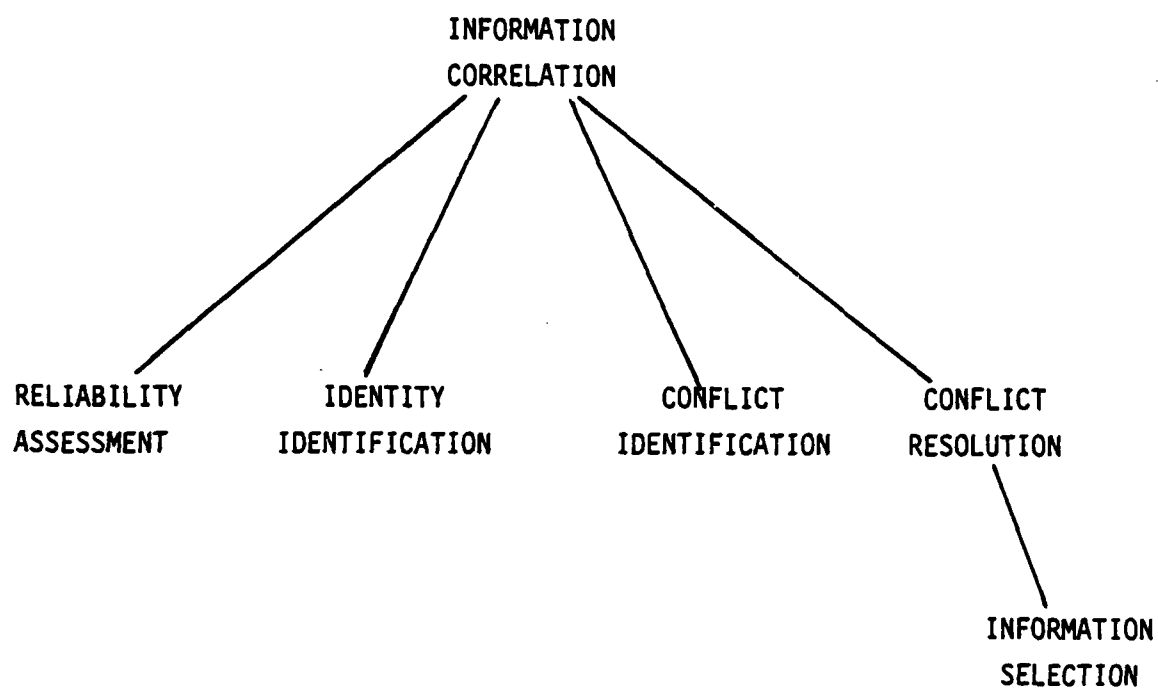


FIGURE 4
DECISION PROCESSES INVOLVED IN
INFORMATION CORRELATION

An improvement in overall concept framework can also be brought about. Note that conflicts in proposed track file modifications could occur not only between division and wing, but also between division and MAF, and wing and MAF. The last two types of conflict differ from the first one only in the sense that the MAF G2 can resolve conflicts acting as the ultimate decision maker. All conflicts, however, involve the same processes and could consequently be treated alike. Thus, a file of proposed track record modifications could be created whose elements would be subjected to analysis to identify and resolve possible conflicts. This would be, of course, a MAF function. The creation of such a file would, in turn, imply centralization of track management functions at MAF level. This would avoid extra communications between MAF, wing, and division with regard to the assignment of track identifiers. This modification which is of an organizational nature would simplify the situation and decrease communication requirements. It should permit an improvement in decision quality and a decrease in processing time.

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